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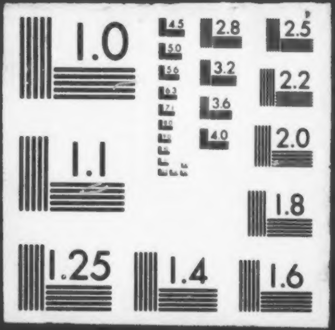

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INDUSTRIAL WASTE SURVEY REPORT. GREAT WESTERN SUGAR COMPANY, STEFFENS HOUSE BEET SUGAR FACTORY, LOVELAND, COLORADO, OCTOBER 17 TO DECEMBER 1, 1949

Graham Walton

Environmental Health Center
Cincinnati, Ohio

1 December 1949

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Industrial Waste Survey Report

GREAT WESTERN SUGAR COMPANY

Steffens House Beet Sugar Factory

Loveland, Colorado

October 17 to December 1, 1949

A Study of the Characteristics of the Individual and Combined Wastes from a Steffens House Beet Sugar Factory

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Environmental Health Center
Cincinnati, Ohio

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Steffens House Beet Sugar Factory

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By

Graham Walton

Sanitary Engineer

FEDERAL SECURITY AGENCY
Public Health Service
Environmental Health Center
Cincinnati, Ohio

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LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY

Industrial Waste Survey Report

ABSTRACT

For the purpose of securing information enabling the estimation of pollution due to waste discharged from Steffens house beet sugar factories, a survey was made of the various wastes from the Loveland, Colorado, Factory of the Great Western Sugar Company. The characteristics of each of the major component wastes were studied for three periods of one week each during October and November, 1949.

In general, the Loveland plant is typical of most Steffens house beet sugar factories. The process by which sugar was extracted from the beets and refined is described, and a detailed flow diagram is included.

In comparing the results of this study with data from other sources, certain factors should be considered. The beets, which had an unusually high sugar content, were received in the factory in a relatively sound and unfrozen condition. The molasses worked, 47.6% of which was shipped in from straight house factories, amounted to 6.26% on beets. This factory used a continuous diffusion unit, the waste from which is believed to be lower in B.O.D. loading than that of comparable waste from factories having multiple-celled diffusion batteries. Finally, it should be noted that some factories press and dry the spent pulp and, thus, eliminate the pulp silo, drainage from which was one of the stronger wastes.

The principal wastes were the Steffens waste, pulp silo drainage, filter cake waste, screened diffusion battery waste, beet washer waste, and flume water waste. Data on the characteristics of each - except the beet washer waste - are given. Included are the volumes in gallons, the B.O.D. in pounds, and the solids in pounds, per ton of beets processed. This information may be used to estimate the B.O.D. loading in wastes discharged into natural waters from Steffens house beet sugar factories comparable to the Loveland Factory.

Of particular concern are the Steffens waste, the pulp silo drainage and the filter cake waste. Although these wastes amounted to only 15.6% of the total volume, they contributed 79.5% of the B.O.D. loading in the combined factory waste.

Although methods for the reduction or elimination of pollution resulting from beet sugar factory wastes were not studied during this survey, some of the possibilities are discussed. The opinion is expressed that the treatment of the large volume of the combined factory waste is not the best solution, but that much can be accomplished through the

clarification and recycling of flume water and beet washer waste; the installation of pulp presses and driers and, thus, the elimination of pulp silo drainage; the treatment and reuse of the screened diffusion battery and pulp press waste; and the impoundment of filter cake waste. Available information also indicates that there is a possibility of eliminating the Steffens waste by utilizing it as a source from which to recover sodium glutamate.

VOLUMES. BIOCHEMICAL OXYGEN DEMAND CONCENTRATIONS, AND POPULATION EQUIVALENTS OF VARIOUS STEFFENS HOUSE BEET SUGAR FACTORY WASTES

WASTE	VOLUME	B.O.D. 5-Day, 20° C.	POPULATION EQUIVALENT (a)
	gal. per ton of beets per day	ppm	Persons per ton of beets per day
Flume Water	2620	223	29.4
Diffusion Battery	406	909	17.8
Steffens	157 (b)	10900	86.7 (c)
Filter Cake	135	7250	49.3
Pulp Silo Drainage	163	8840	68.7
Other (d)	729	-	46.1
Combined Factory	4210	1400	298.0

(a) Based on 0.167 pound of 5-day, 20°C. B.O.D. per capita per day

(b) This amounts to 2420 gallons per ton of 50% polarization molasses processed

(c) The population equivalent for each ton of 50% polarization molasses processed per day is 1330 persons

(d) Balance for summation to equal data for combined factory waste

GENERAL INFORMATION

This report covers the study of Steffens house beet sugar factory wastes conducted at the Loveland Factory of the Great Western Sugar Company, located at Loveland, Colorado.

1. Organization of Survey

This survey was a cooperative survey conducted by the Great Western Sugar Company and the Environmental Health Center of the U. S. Public Health Service. The Colorado State Game and Fish Department assisted by providing a sampler, and the U. S. Bureau of Reclamation furnished a car for transportation.

At various times, both prior to its undertaking and during the period of the study, conferences of the technical staffs of the organizations were held to plan its course.

2. Dates of Survey

The field survey extended from October 17, 1949 through December 1, 1949. The individual and combined factory wastes were studied during three separate periods - starting October 17, November 7, and November 27 - each of which included four or five days of sampling.

3. Personnel Participating

The following personnel cooperated or participated in this study:

GREAT WESTERN SUGAR COMPANY
  Denver Office
    A. A. Clark, Vice President and General Superintendent
    C. E. Hirsch, Chief Engineer
    E. H. Hungerford, General Chemist
    A. R. Nees, Superintendent, Research Laboratory
    C. H. Criswell, District Superintendent
  Loveland Factory
    F. A. Whiting, Manager
    E. G. Gonyu, Plant Superintendent
    H. F. Davies, Master Mechanic
    V. V. Hartman, Chief Chemist
    A. J. Brandt, Sampler

PUBLIC HEALTH SERVICE
    H. H. Black, Chief, Industrial Wastes Section
    C. T. Carnahan, Engineer in Charge, South Platte River Basin Water Pollution Investigation
    Graham Walton, Project Engineer

J. M. Cohen, Project Chemist
William Bjorklund, Technical Aid
Douglas Stevenson, Sampler *

*Employed by Colorado State Game and Fish Department

4. Purpose

This survey was made to secure information which would enable the estimation of the pollution, and particularly the B.O.D. loading of wastes discharged from Steffens house beet sugar factories using equipment and processes comparable to those used by the Loveland Factory. A secondary purpose was the exploration of the possibilities for the reduction in the pollution resulting from the discharge of such wastes into natural waters.

5. Location of Factory

The Loveland Factory of the Great Western Sugar Company is located in the eastern outskirts of Loveland, Colorado.

6. Raw Materials

The principal raw materials were sugar beets and the molasses shipped in from the straight house beet sugar factories. Other materials which were used included: coal for generating heat and power; coke and limestone for producing carbon dioxide; limestone for making lime; sulfur for producing sulfur dioxide; and water.

7. Products

The Loveland Factory produced granulated white sugar. Part of the by-product molasses was shipped to the Johnstown Factory for recovery of additional sugar by the barium process. Still another by-product was the spent beet pulp. This was stored in an open silo and eventually sold as feed for cattle.

8. Operation

Operation is seasonal. The 1949 campaign commenced October 7, and terminated December 23. Throughout this period the factory operated continuously, 24 hours per day, seven days a week.

The normal rated processing capacity of the factory was 2,500 tons of beets per day. The tons of beets sliced for each of the days on which samples were collected averaged 2,482, and varied from 1,834 to 2,590 tons per day.

9. Employees

The factory employed 277 persons, including 4 office employees. This was slightly under the 281 employees permitted under the allotment plan of the Great Western Sugar Company.

10. Water Supply

Water was obtained from two sources. That for drinking and other very limited uses was City of Loveland water. All other water, such as that used for fluming beets and in factory processes, was drawn from an irrigation ditch of the Greeley and Loveland Irrigation Company. Condensed process water was used for steam generation.

11. Wastes

All factory wastes - flume water and beet washer wastes, screened diffusion battery waste, water-borne filter cake, pulp silo drainage, settled ash pit drainage, wash water, and roof and surface water - were discharged into the main factory sewer and thence into an irrigation ditch of the Greeley and Loveland Irrigation Company.

12. Sanitary Sewage

Sanitary sewage was discharged into the factory sewer along with the other factory wastes.

13. By-Product Recovery and Waste Treatment

a. Diffusion Battery Waste - The spent beet pulp was recovered from the diffusion battery waste by means of an A-frame screen (a Faenger screen was used following the collapse of the A-frame screen supports on November 25). The screen effluent was then discharged into the sewer.

b. Beet Washer Wastes - The roller picking table spray wash was screened to remove the tailings before being discharged into the sewer.

c. Ash Pit Drainage - The water used to transport ashes from the ash pit flowed through a settling lagoon and then into the sewer.

All wastes, including the sanitary sewage, were eventually discharged into a large lagoon, any overflow from which went into the Big Thompson River.

DISCUSSION OF PROCESS

The Loveland Factory was constructed in 1901. It is one of seventeen beet sugar factories owned and operated by the Great Western Sugar Company. Although it is one of the oldest factories in this area, extensive improvements have made it one of the most modern factories operated by this company.

Harvest of beets for the 1949 campaign in this area commenced around October 1, and was practically completed by November 10. The harvested beets were either temporarily stored in piles at field stations or transported directly to the factory. In general, the yield per acre was high and the sugar content, which through December 1 averaged 16.5%, was the best on record. Weather conditions were favorable and the beets arrived at the factory in a relatively sound and unfrozen condition.

14. Manufacturing Processes

The beets were delivered to the yard where they were stored in bins over lateral flumes which terminate in a header extending into the factory. As needed, they were discharged into the flume to float or roll into the factory. En route they passed a beet rate-controller - a paddle wheel revolving counter to the flow - and two trash hooks, each of which consisted of several hook-like rakes suspended on two endless chains. These rakes dipped into the water and in moving upstream picked up the beet tops, weeds, etc. This material was sold as cattle feed. Finally, the beets passed through a stone catcher.

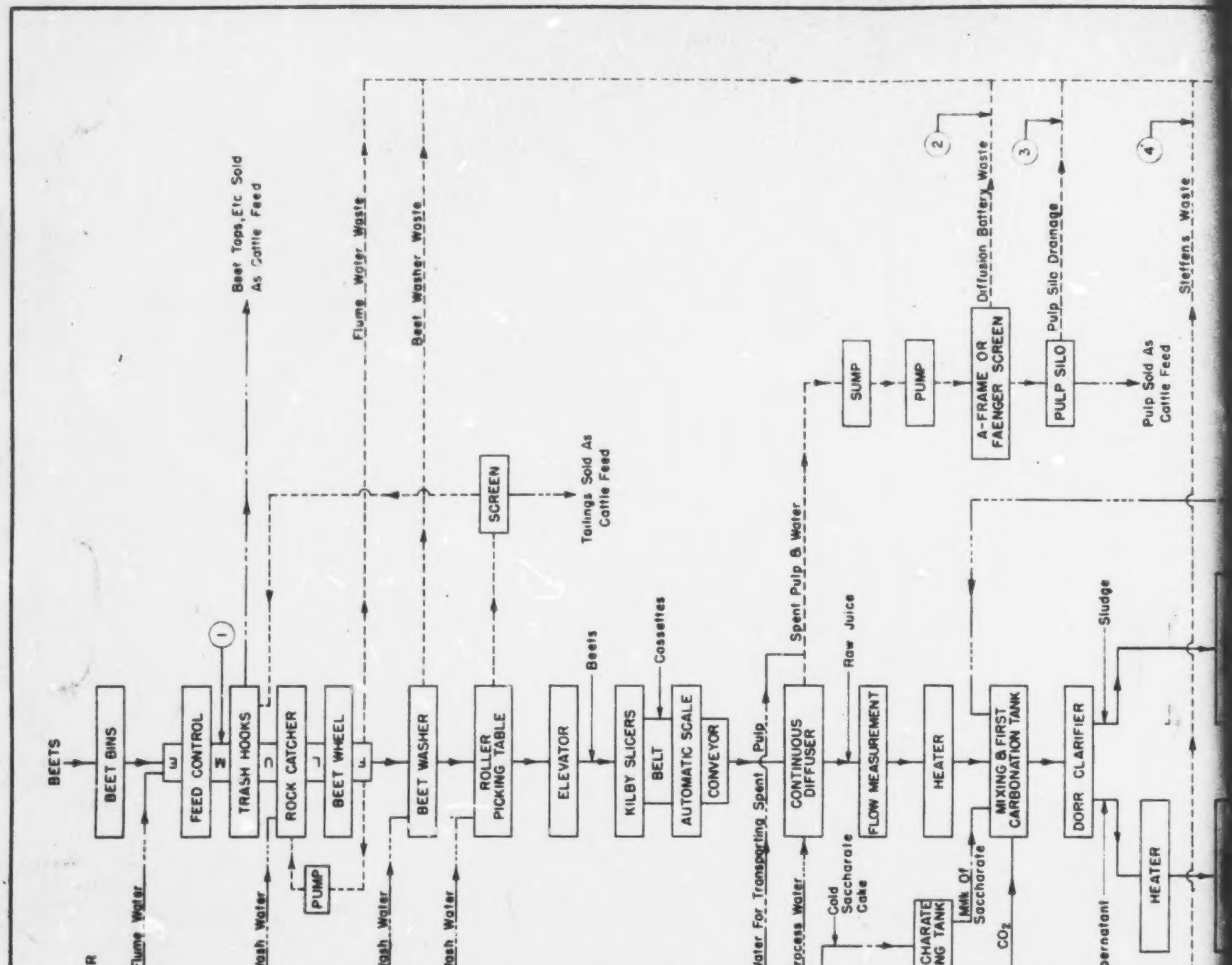
The flume terminated at the beet wheel (see Flow Diagram, Fig. 1), which lifted the beets from the flume and discharged them into the washer. The flume water, which had been used to transport the beets into the factory and to remove most of the sand and soil, flowed through openings in the beet wheel and thence into the sewer.

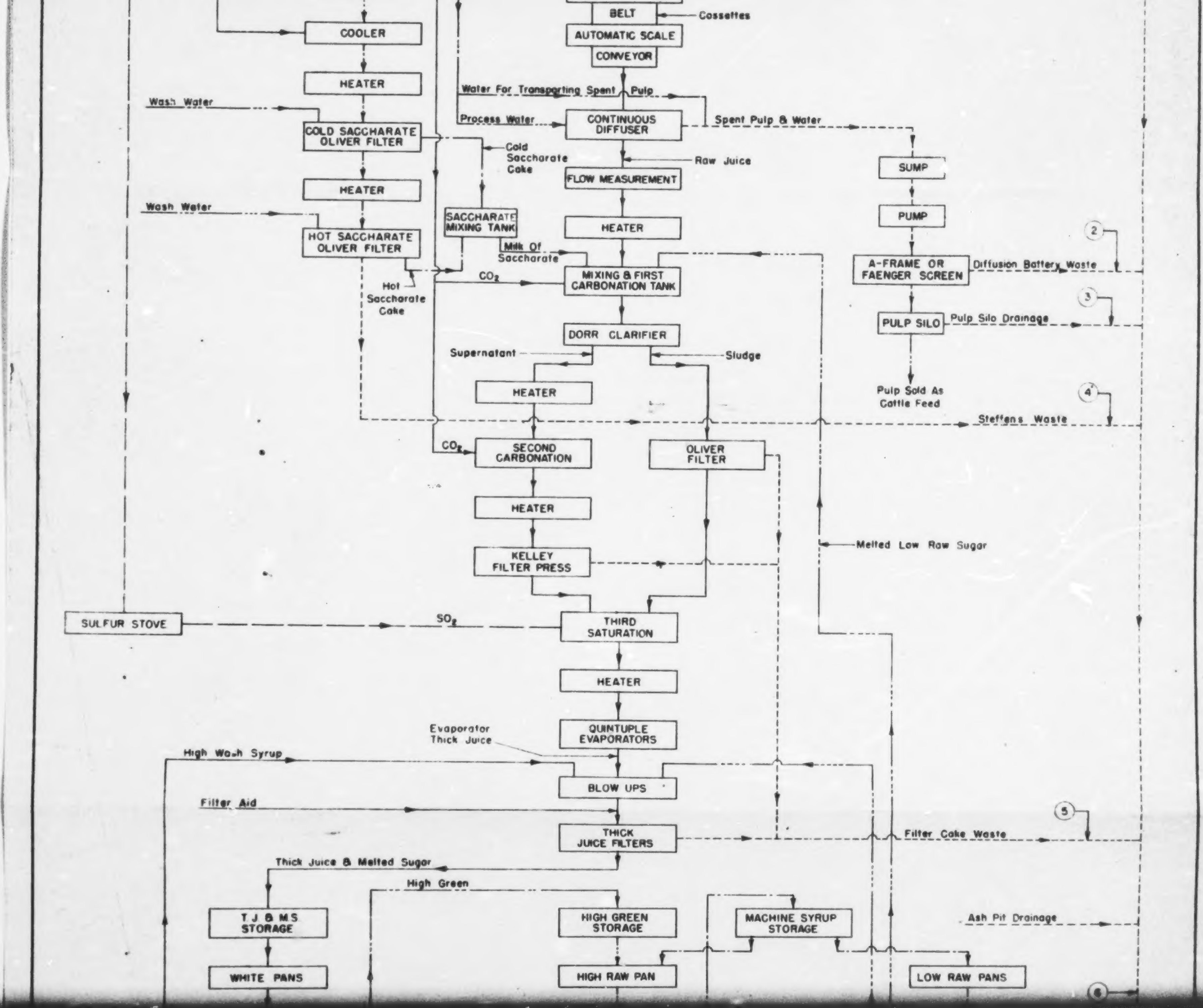
In the washer the beets were agitated in clean water by revolving blunt paddles. This freed them of most of the remaining dirt and debris. From the washer the beets passed through a final spray wash as they moved over a roller table to the elevator. This wash water passed between the rollers and then flowed through an A-frame screen and into the sewer.

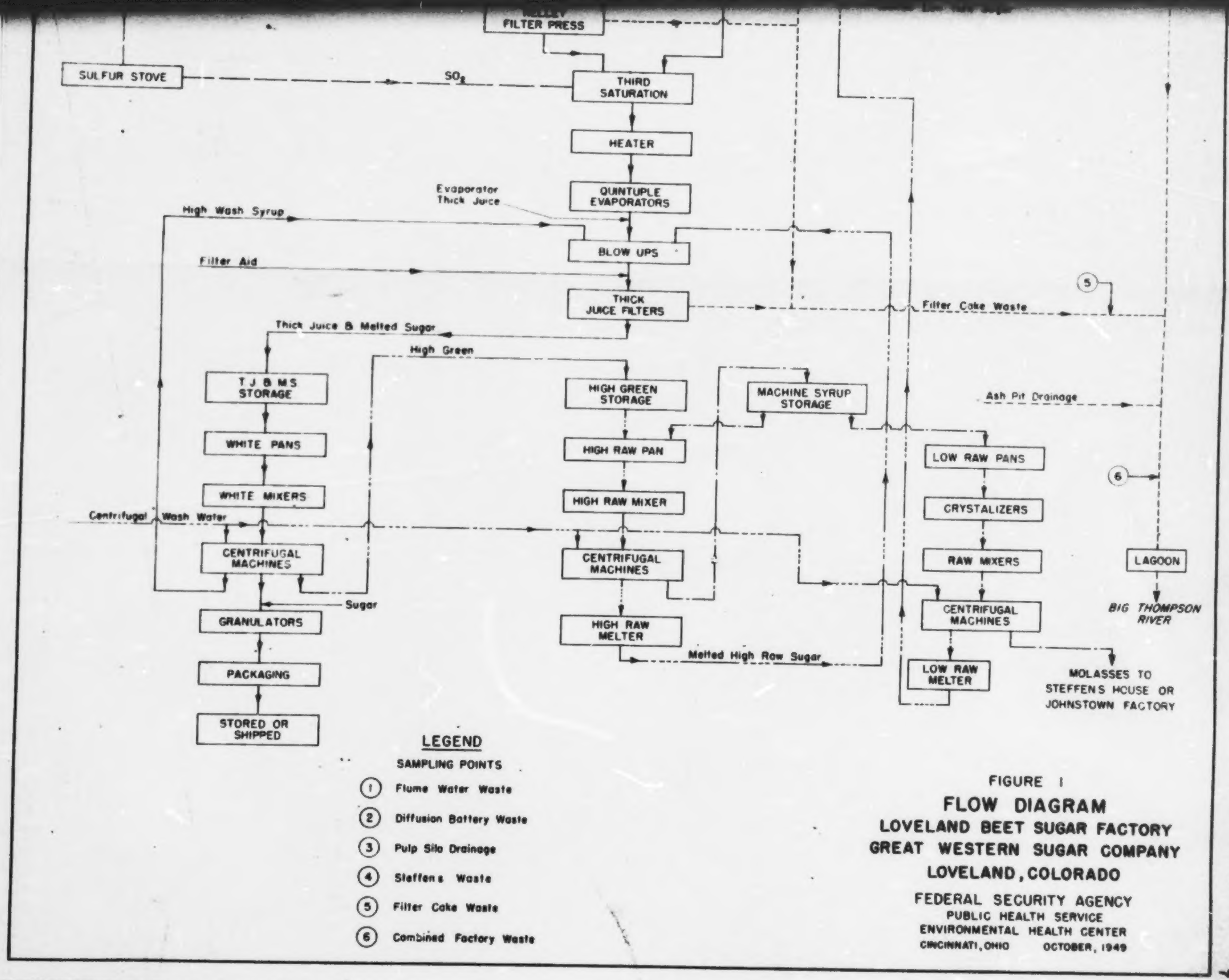
The elevator lifted the clean beets to the top of the factory and dumped them onto a picking table which discharged them into the Kilby slicers.

In the Kilby slicers V-shaped knives rotating in a horizontal plane cut the beets into small, noodle-like strips, called "cossettes" or "noodles." From the slicers the cossettes were discharged onto a belt conveyor which transported them over a continuous recording automatic scale and discharged them into the diffusion battery.

This diffusion battery was a Silverman continuous diffusion unit consisting of several compartments. The cossettes were admitted at one end and the spent pulp was withdrawn from the other. Sugar was extracted by passing hot


BEETS
WATER
LIMESTONE
COKE
MOLASSES
SULFUR
BEET BINS
E
FEED CONTROL
M
TRASH HOOKS
C
ROCK CATCHER
J
BEET WHEEL
L
BEET WASHER
ROLLER PICKING TABLE
ELEVATOR
KILBY SLICERS
BELT
AUTOMATIC SCALE
CONVEYOR
CONTINUOUS DIFFUSER
FLOW MEASUREMENT
HEATER
MIXING & FIRST CARBONATION TANK
DORR CLARIFIER
HEATER
1
Beet Tops, Etc Sold As Cattle Feed
Flume Water Waste
Beet Washer Waste
SCREEN
Tailings Sold As Cattle Feed
Beets
Cossettes
Spent Pulp & Water
Raw Juice
Sludge
Supernatant
SUMP
PUMP
A-FRAME OR FAENGER SCREEN
PULP SILO
Pulp Sold As Cattle Feed
2
Diffusion Battery Waste
3
Pulp Silo Drainage
4
Steffens Waste
Flume Water
Wash Water
PUMP
Wash Water
Wash Water
Water For Transporting Spent Pulp
Process Water
Cold Saccharate Cake
SACCHARATE MIXING TANK
Milk Of Saccharate
CO2
LIME KILN
CRUSHER
RAYMOND MILLS
FAN
CYCLONE
ELEVATOR
STORAGE BIN
SCALES
COOLER
HEATER
COLD SACCHARATE OLIVER FILTER
HEATER
HOT SACCHARATE OLIVER FILTER
Hot Saccharate Cake
Cold Water
COOLER SOLUTION TANK
Wash Water
Wash Water


BELT
Cossettes
AUTOMATIC SCALE
CONVEYOR
COOLER
HEATER
Wash Water
Water For Transporting Spent Pulp
Process Water
CONTINUOUS DIFFUSER
Spent Pulp & Water
COLD SACCHARATE OLIVER FILTER
Cold Saccharate Cake
Raw Juice
SUMP
FLOW MEASUREMENT
HEATER
Wash Water
SACCHARATE MIXING TANK
PUMP
HEATER
HOT SACCHARATE OLIVER FILTER
Milk Of Saccharate
2
A-FRAME OR FAENGER SCREEN
Diffusion Battery Waste
CO_2
MIXING & FIRST CARBONATION TANK
Hot Saccharate Cake
3
PULP SILO
Pulp Silo Drainage
DORR CLARIFIER
Supernatant
Sludge
HEATER
Pulp Sold As Cattle Feed
4
Steffens Waste
CO_2
SECOND CARBONATION
OLIVER FILTER
HEATER
Melted Low Raw Sugar
KELLEY FILTER PRESS
SULFUR STOVE
SO_2
THIRD SATURATION
HEATER
QUINTUPLE EVAPORATORS
Evaporator Thick Juice
High Wash Syrup
BLOW UPS
Filter Aid
5
THICK JUICE FILTERS
Filter Cake Waste
Thick Juice & Melted Sugar
High Green
T J & MS STORAGE
HIGH GREEN STORAGE
MACHINE SYRUP STORAGE
Ash Pit Drainage
WHITE PANS
HIGH RAW PAN
LOW RAW PANS
6



FILTER PRESS
SULFUR STOVE
SO_2
THIRD SATURATION
HEATER
QUINTUPLE EVAPORATORS
Evaporator Thick Juice
High Wash Syrup
BLOW UPS
Filter Aid
THICK JUICE FILTERS
Filter Cake Waste
5
Thick Juice & Melted Sugar
High Green
T J & M S STORAGE
HIGH GREEN STORAGE
MACHINE SYRUP STORAGE
Ash Pit Drainage
WHITE PANS
HIGH RAW PAN
LOW RAW PANS
6
WHITE MIXERS
HIGH RAW MIXER
CRYSTALIZERS
Centrifugal Wash Water
CENTRIFUGAL MACHINES
CENTRIFUGAL MACHINES
RAW MIXERS
LAGOON
Sugar
GRANULATORS
HIGH RAW MELTER
CENTRIFUGAL MACHINES
BIG THOMPSON RIVER
Melted High Raw Sugar
LOW RAW MELTER
MOLASSES TO STEFFENS HOUSE OR JOHNSTOWN FACTORY
PACKAGING
STORED OR SHIPPED
LEGEND
SAMPLING POINTS
① Flume Water Waste
② Diffusion Battery Waste
③ Pulp Silo Drainage
④ Steffens Waste
⑤ Filter Cake Waste
⑥ Combined Factory Waste

FIGURE I

FLOW DIAGRAM
LOVELAND BEET SUGAR FACTORY
GREAT WESTERN SUGAR COMPANY
LOVELAND, COLORADO

FEDERAL SECURITY AGENCY
PUBLIC HEALTH SERVICE
ENVIRONMENTAL HEALTH CENTER
CINCINNATI, OHIO OCTOBER, 1949

water, the temperature of which was gradually increased to a maximum of between 80 and 85°C., through the compartments. The counter flow principle was used; the fresh water entered the battery at the end from which the cossettes were withdrawn, and the raw juice - the water of highest sugar content - was drawn from the end containing the freshly admitted cossettes. Water was added to the spent cossettes, which were dumped from the diffusion battery, to enable their being pumped to the pulp silo.

The raw juice was measured and sent through a preheater to the mixing and first carbonation tank, where milk of saccharate was added. This milk of saccharate was obtained by the Steffens process in which the molasses was treated with powdered lime under carefully controlled conditions. The resulting mixture was thoroughly agitated, then carbon dioxide gas was added until much of the calcium in the milk of saccharate had been precipitated as calcium carbonate. When the carbonation had reached the desired point, the mixture was sent to the Dorr clarifier, where most of the lime sludge - the calcium carbonate and the impurities contained therein - was settled. The supernatant flowed through a preheater to the second carbonation tank. Here practically all the remaining calcium was precipitated with carbon dioxide. The juice then passed through a heater to the second filter presses, where lime cake was again removed. The second press filtrate, together with the juice obtained by filtering the sludge from the Dorr clarifier through an Oliver filter, was then treated with sulfur dioxide gas.

The purified thin juice, which contained 10% to 13% sugar, was heated and then entered the quintuple evaporators where it was concentrated to a syrup containing about 60% sugar. This concentrate or thick juice, together with melted sugar and high wash, went to the blow ups, which were mixing and heating tanks. Filter aid, a diatomaceous earth, was added and the resulting mixture filtered through the thick juice filters. The filtered thick juice was then drawn into the white vacuum pan, where it was evaporated to that concentration which on crystallization would give the desired granular size. This mass of crystals and the mother liquor were called the "white massecuite." From the white pan the massecuite was discharged to the centrifugals, basket-like screens which were revolved at high speed. The granulated sugar was retained on the screens through which the mother liquor, called the high green, flowed. Since some of the impure syrup remained on the crystals, they were finally washed with a fine spray of hot water. The resulting syrup was known as the high wash.

The washed sugar was then dried in the granulators and sacked, while the high wash was returned to the blow ups, and the high green went to the intermediate or high raw pan.

The high green which passed to the high raw pan was processed in a manner similar to that described above. The resulting impure sugar went to the high raw melter and thence back to the blow ups, and the mother liquor, or machine syrup, passed into either the high or low raw pans. Except for the use of crystallizers - large cooling tanks - the low raw process was similar to the high raw process. The sugar from the low raw centrifugals was discharged into the low raw melter and then returned to the first carbonation tank, while the mother liquor, or molasses, was either returned to the Steffens process or shipped to the Johnstown factory where additional sugar was recovered by means of the barium process.

The final product was a white granulated sugar of nearly 100% purity. More or less typical analyses of such sugar show the following foreign substances: Moisture 0.025%; mineral ash 0.009%; sulfates, less than 5 ppm; and organic non-sugars, trace.

15. Wastes

Since the sugar beet is the principal source of the organic matter in the wastes, its composition is of interest. According to Molinari (1)[1], the principal constituents of the sugar beet root are:

Constituent	Per Cent
Water	75 to 86
Sucrose	9 to 18
Cellulose Lignin	0.8 to 2.5
Nitrogenous matter, protein and amino	0.8 to 3.0
Fats	0.2 to 0.5
Potassium and other mineral salts	0.2 to 2.0

Other substances which are present in small amounts are: glucose, raffinose, organic acids (oxalic, tartaric, citric, malonic, succinic, and gluconic), amines and amino compounds (leucine, asparagin, betaine and tyrosine), gums, pectic matters and coniferin. These and other substances, such as lime and sulfur, undoubtedly occur in varying concentrations in the factory wastes.

---

[1] Numbers in parenthesis refer to references listed in bibliography.

a. Condenser Water - The condenser water included the condensed steam and vapors from the steam turbine, heat exchangers, the evaporators and the several pans. Since at this factory all condenser water was used for flume and process water, boiler feed, transportation of filter cake or other purposes, it has not been considered a waste. In fact, it was usually used wherever a relatively pure water was desired.

b. Flume Water Waste - The flume water was composed of condenser and irrigation water. In transporting the beets from the storage bins to the beet wheel it became laden with considerable quantities of mud, sand and debris. The amount of such matter has been reported to vary with the soil conditions (wet or dry) and the method (hand or machine) under which the beets are harvested. Stones, weeds, beet tops and other foreign material were present in relatively small quantities. The strength of this waste has been reported to vary with the percentages of beets which are imperfect, broken or damaged by frost.

c. Beet Washer Waste - The beet washer waste resulted from the mechanical agitation of beets and water in the washing tank, and from the high pressure spray directed onto the beets as they moved along the roller table. The latter was screened to remove the tailings which were sold as cattle feed.

d. Diffusion Battery Waste - The waste discharged from the continuous diffusion battery was largely spent pulp. Water was added as necessary to permit hydraulic transportation of this waste. On reaching the pulp silo the spent cossettes were removed by an A-frame screen (a Faenger screen was used after November 25). These fell into the silo and the screened diffusion battery waste was discharged into the sewer.

e. Pulp Silo Drainage - The pulp silo drainage was the waste which collected in and drained through the underdrainage of the large open silo in which the spent cossettes were received and stored until removed for use as feed for cattle. The liquid portion of this waste originated from the diffusion battery waste which failed to pass the A-frame or Faenger screens, also from rain or other precipitation.

Fig. 2. The A-frame screen used to remove the tailings from the roller table spray wash.

Fig. 3. A view of the pulp silo showing the Faenger screen.

f. Filter Cake Waste - The filter cake waste was the slurry resulting on the addition of water to enable water-carriage of the lime and other cake removed by the filters following the carbonation and sulphitation treatments. This water-borne cake contained calcium carbonate, calcium sulfate and filter aid, together with the impurities removed from the molasses and raw juice.

g. Steffens Waste - In the Steffens process the molasses was treated with powdered lime under carefully controlled conditions to precipitate the succrose as calcium saccharate. The resulting slurry was filtered to recover the saccharate and the filtrate was discharged as Steffens waste.

h. Combined Factory Waste - The combined factory waste included all liquid and liquid-carried wastes discharged from the factory. These wastes were; flume water and beet washer wastes, screened diffusion battery waste, pulp silo drainage, Steffens waste, and filter cake waste, together with the settled ash pit drainage, floor washings, roof and surface drainage, and sanitary sewage.

SURVEY PROCEDURES

16. Sample Collection and Compositing

During the period of this survey samples were collected of the flume water waste, the screened diffusion battery waste, the Steffens waste, the filter cake waste, the pulp silo drainage, and the combined factory waste. All samples were collected by an employee of the factory during the 8-hour shift commencing at 8:00 A.M. Every reasonable precaution was taken to insure the collection of representative samples.

Each composite sample consisted of eight one-quart portions collected at approximately hourly intervals. In general, the flow of each waste was reasonably constant and the operation of the factory was quite uniform; therefore, the resulting 8-hour composites are considered to be truly representative of the wastes.

Immediately after collection each portion was poured into the 3-gallon carboy used for compositing that sample. Except in the case of the filter cake waste, each carboy was set in a wooden box and packed in ice. The temperatures of the composited samples immediately following

Fig. 4. The carboys used in compositing the individual samples were packed in ice.

collection of the final portion and after thorough mixing usually varied between 10 and 15°C. In a few cases they were found to be as high as 20°C. The lime content of the filter cake waste made icing unnecessary.

After completion of the sample collection each carboy containing a sample was thoroughly shaken and immediately inverted to fill a 2-quart jar. These jars were then packed in ice for transportation and until the following morning when removed for analyses at the Environmental Health Center Field Laboratory at Greeley.

17. Flow Measurements

The determination of the relative pollution due to the individual factory wastes requires data on both the strength and volume of each waste. Thus, where considered necessary and practical a weir or Parshall flume was installed to determine the discharge of each waste.

Table 1 summarizes data on the flow measurement devices used, the formulas employed for preparing discharge tables, and the probable accuracy of the data obtained. Where staff gages were used, readings were taken at approximately hourly intervals during the 8-hour period of sample collection.

The Parshall flume for measuring the combined factory waste was installed in the irrigation ditch about 2 miles downstream from the factory. Several days records were lost due to the diversion of factory waste for irrigation purposes. Still other flow records were discarded due to silting of the tube connecting the stilling well to the flume. However, the data collected shows a very uniform daily flow and the average discharge of 10,470,000 gpd checks exceedingly well with the average factory water consumption of 11,000,000 gpd recorded by the Greeley and Loveland Irrigation Company.

TABLE 1. FLOW MEASUREMENTS AND THEIR PROBABLE ACCURACY - LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY - OCTOBER - NOVEMBER, 1949

WASTE	MEASURING DEVICE	FORMULA	REMARKS	PROBABLE ACCURACY
Flume Water	None		Flow estimated at 10 cfs by technical staff at factory; surface velocity and flow through area measurement gave 9.6 cfs	?
Beet Washer	None		Estimated Flow based on Windsor data	?
Diffusion Battery	90° V-Notch Weir & Staff Gage	King (2) $Q = 2.52H^{2.47}$	Variable flow; fair velocity of approach conditions; weir crest not sharp-edged; head around 0.90 ft; foam obscured water surface	± 10%
Steffens	None	$V = \frac{A \times B \div 2000}{8.34 \times C}$	Computed from factory records	± 3%
Filter Cake	None	$V = \frac{D \times 2000}{8.34 \times E}$	Computed from factory records	± 20%
Pulp Silo Drainage	90° V-Notch Weir & Staff Gage	King (2) $Q = 2.52H^{2.47}$	Reasonably steady flow; good velocity of approach conditions; weir crest not sharp edged; head around 0.60 ft; reading gage difficult because of angle	± 5%
Ash Pit Drainage	None	-	Estimated by cross section area and parabolic curve of jet	± 20%
Combined Factory	36" Parshall Flume & Continuous Water Level Recorder	Parshall (3) $Q = 8\ H_a^{1.522W^{0.026}}$	Steady flow; fair velocity of approach conditions; tube to stilling well projected slightly into flume; head around 1.20 ft. Some difficulty with stoppage at connecting tube	± 5%

Notes

A - 50% polarization molasses worked in tons per day
B - Waste water per ton of 50% polarization molasses worked in tons
C - Specific gravity of Steffens waste = 1.014
D - Filter cake waste per day in tons (determined from pounds CaO used and average CaO concentration in waste)
E - Specific gravity of filter cake waste = 1.06
H - Head on weir or flume crest in feet
Q - Discharge in cfs
V - Discharge in gpd

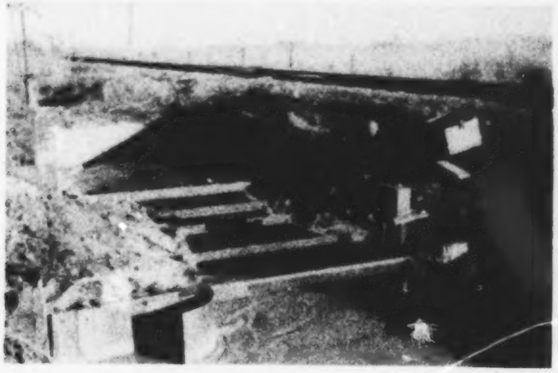


Fig. 5. Looking downstream at the 36-inch Parshall flume installed to measure the combined factory waste.

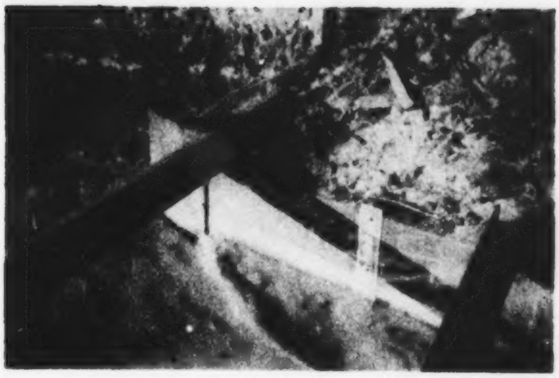


Fig. 6. Poor velocity of approach conditions affect head readings.

Laboratory Procedures

The following analytical results are reported for samples collected during this survey:

Temperature
pH
Alkalinity, total and phenolphthalein
Acidity
Biochemical Oxygen Demand (BOD)
Total Solids as total, suspended and filtrable
Volatile Solids as total, suspended and filtrable
Ammonia Nitrogen
Organic Nitrogen

Total and total fixed solids, and the suspended total and fixed solids, were actually determined; all other results on solids were computed therefrom. The organic nitrogen concentrations reported were obtained by the difference between the total and ammonia nitrogen values.

In general, the analytical procedures employed are those given in "Standard Methods for the Examination of Water and Sewage," 9th Edition (Ref. 16).

EXPLANATION OF ANALYTICAL DETERMINATIONS

A brief explanation of the various laboratory determinations is given below to aid in the interpretation of the analytical results reported.

19. Temperature

The reported average, maximum and minimum tempratures in °C are those determined by temperature readings on each hourly portion of the sample.

Such data may be significant for the detection of abnormal discharges into a given industrial waste and for the possible influence upon biological or chemical treatment processes.

20. pH

The symbol "pH" denotes the logarithm of the reciprocal of the hydrogen-ion concentration of the water, sewage or waste. It is a measure of the relative intensity of the acidity or alkalinity, and not of the amount of acid or alkali present. Solutions having a pH below 7.0 have acidity; those having a pH above 7.0, an alkalinity.

In each case the intensity changes very rapidly as the pH departs from the neutral value of 7.0.

The pH may be significant for the detection of an abnormal discharge into a given waste, also for its influence on biological decomposition and chemical treatment processes. As regards the pollution of natural waters, extreme ranges of pH may affect aquatic life and increase costs of treatment of a water used for domestic or industrial purposes.

21. Alkalinity

The alkalinity of a water or waste represents its content of carbonates, bicarbonates and hydroxides; and, although rarely present in significant quantities, of borates, silicates and phosphates of the alkali and alkali earth metals. The calcium and magnesium alkalis or salts usually account for most of the alkalinity.

In the titration with the standard acid two end-points are sometimes used. The first, or phenolphthalein end-point, measures the hydroxides plus one-half the normal carbonates; the second, or methyl-orange end-point, corresponds to the total alkalinity. In each case the alkalinity is expressed in terms of the equivalent parts per million (ppm) of calcium carbonate ($CaCO_3$).

The discharge of a highly alkaline waste into a natural water course may be of concern when such water is used as a source for domestic or industrial water supplies, and in extreme cases where the water is used for irrigation.

22. Acidity

The acidity of a water or waste represents the content of free carbon dioxide, mineral and organic acids, and those acid salts which hydrolize to give hydrogen ions. It is expressed in terms of the parts per million of calcium carbonate ($CaCO_3$) equivalent to the acid neutralized on titration with a strong alkali to the phenolphthalein end point.

23. Biochemical Oxygen Demand (BOD)

The biochemical oxygen demand (BOD) of a sewage, sewage plant effluent, polluted water, or industrial waste is the oxygen required during stabilization of the organic matter undergoing aerobic biological decomposition. The time and temperature values generally used for this analysis are 5 days and 20°C. Approximately 68% of the ultimate BOD of a normal domestic sewage is satisfied upon incubation for 5 days at 20°C. However, this ratio of 5-day to ultimate BOD does not necessarily hold for industrial waste. In such cases the rate of oxygen utilization may be affected by the carbon-nitrogen ratio, the presence of substances inhibiting biological decomposition, or other factors.

The BOD determination is significant as a measure of the relative strength of the sewage, sewage plant effluent, river water or of certain industrial wastes. It also indicates the possible extent and duration of oxygen depletion of the receiving water. Depletion of oxygen in natural waters may destroy fish and other aquatic life, and result in the production of obnoxious odors.

24. Population Equivalent

Normal domestic sewage, relatively free from industrial wastes, possesses characteristics which are reasonably well defined. It is therefore possible to compare sewages on a common basis. Industrial wastes, however, vary greatly according to the nature of the industry and the particular processes employed. They have no well defined characteristics.

Thus, the "Population Equivalent" has been used to compare the loading of each of the various wastes with that of a normal domestic sewage, reasonably free from industrial wastes. In this report the population equivalent has been based on 0.167 pounds of 5-day 20°C. BOD per capita per day (4), which was the value determined by averaging the results obtained for several domestic sewages, reasonably free from industrial wastes.

25. Solids

Solids are reported as total and volatile solids, with each of these being subdivided into total, suspended and filtrable - sometimes referred to as "dissolved" - solids. The actual analyses included only the total and total fixed solids, and the suspended total and fixed solids; all other data reported were calculated therefrom.

Normally the volatile solids are considered to be organic material. However, in case of lime bearing wastes - the filter cake and combined factory wastes - the volatilization of carbon dioxide from the calcium carbonate results in high volatile solid values.

For domestic sewage the volatile and suspended solids data usually show a definite relation to BOD. However, this is seldom true for an industrial waste. The principal value of these determinations is that they indicate the amount of settleable material, both organic and inorganic, contained in the various wastes.

26. Ammonia Nitrogen

Ammonia nitrogen is reported as the parts per million of nitrogen present in the form of ammonia (NH_3). Since ammonia is the first step in the breakdown of nitrogenous organic matter, the relative amount of ammonia present in a waste may be indicative of its freshness.

27. Organic Nitrogen

The organic nitrogen is reported in parts per million of nitrogen in the form of proteins and their decomposition products, amino acids, and other nitrogenous matter.

This determination indicates the relative strength of the waste, as concerns the decomposable nitrogenous matter.

DISCUSSION OF RESULTS

The average characteristics of Steffens house beet sugar factory wastes as determined by this study are shown in Table 2. Records of the daily flows and the analytical results for each sample collected may be found in the Appendix A. In general, the analytical data are given in parts per million (ppm) by weight; however, an exception are those for the filter cake waste which are reported in milligrams per liter (mg/l.). This unit has been used because laboratory sampling was on a volumetric basis, and the specific gravity of this waste was approximately 1.06.

28. Flume Water Waste

The flume water waste flow, as estimated by the technical staff of the factory, and as checked by surface velocity and flow-through cross-section area, was approximately 6,460,000 gpd, or 2,620 gallons per ton of beets processed. It included condenser water and had an average temperature of 31°C. The pH and alkalinity were within a normal range for natural waters in this area.

The 5-day, 20°C, BOD, as determined for seven samples, averaged 223 ppm, and varied from 155 to 262 ppm. This is comparable to a normal domestic sewage. The BOD amounts to 4.90 pounds per ton of beets sliced, which is slightly higher than the values given by Eldridge (5), and as determined for the Windsor Factory (7) (see Table 5).

The total suspended solids averaged 4,110 ppm, or about 90 pounds per ton of beets. Volatile solids averaged 660 ppm. The average concentrations of organic and ammonia nitrogen were 12.9 and 3.3 ppm, respectively.

TABLE 2 - AVERAGE CHARACTERISTICS OF STEFFENS HOUSE BEET SUGAR FACTORY WASTES - LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY, OCTOBER-NOVEMBER, 1949

Determination	Flume Water Waste	Diffusion Battery Waste	Steffens Waste	Filter[(a)] Cake Waste	Pulp Silo Drainage	Combined Factory Waste
Volume (gal. per ton of beets)	2620	406	157	135	163	4210[(b)]
(gal. per ton of 50% polarization molasses)			2420			
Temperature (°C.)	31	28	-	-	27	26
pH	7.7	6.9	12.6	11.6	3.8	10.7
Alkalinity, Phenolphthalein (ppm, as CaCO$_3$)	-		5586	3300	-	274
Alkalinity, Total (ppm, as CaCO$_3$)	145	111	8212	59400	2860[(c)]	2388
B.O.D., 5-day, 20°C. (ppm)	223	909	10940	7254	8841	1404
Total Solids, Total (ppm)	4413	1795	24710	149000[(d)]	6779	8080
Suspended (ppm)	4113	1020	90	145000[(d)]	829	6340
Filterable (ppm)	333	775	24900	4000[(d)]	5950	1740
Volatile Solids, Total (ppm)	650	1143	10950	17200[(d)]	5982	2140
Suspended (ppm)	393	801	40	15500[(d)]	767	900
Filterable (ppm)	257	342	11270	1700[(d)]	5215	1240
Nitrogen, NH$_3$ (ppm)	3.3	5.0	8.5	3.3	7.2	2.9
Organic (ppm)	12.9	33.2	832	362.	89	69.7

(a) Analytical results for filter cake wastes are reported in mg/1. instead of ppm, to obtain ppm divide by specific gravity = 1.06.

(b) Includes beet washer wastes and ash pit drainage which are estimated to be 500 and 510 gallons per ton of beets, respectively.

(c) Acidity.

(d) Results of a single analytical determination.

29. Beet Washer Waste

The beet washer waste was not sampled due to the difficulty of measuring its flow and of securing representative samples. The flow as based on the estimate for the Windsor factory would be 1,240,000 gpd, or 500 gallons per ton of beets processed.

For the purpose of determining the relative BOD loadings of the various wastes, this waste has been assumed to have the same BOD concentration as the flume water waste.

30. Diffusion Battery Waste

The screened waste from the continuous diffusion unit averaged 1,005,000 gpd, or 406 gallons per ton of beets processed. The pH and alkalinity were reasonably normal for natural waters in this area, averaging 6.9 and 111 ppm, respectively. The BOD varied from 5[illegible]0 to 1,420, and averaged 909 ppm. However, the pounds per ton of beets was only 2.98, which is considerably less than the 5.8 indicated by Eldridge (5) and 5.54 found for wastes from the multiple-cell diffusion battery at the Windsor Factory.

The suspended solids concentration averaged 1,020 ppm, 800 ppm of which were volatile. Total volatile solids averaged 1,140 ppm. This waste contained an average of 33.2 ppm organic nitrogen and 5.0 ppm ammonia nitrogen.

31. Pulp Silo Drainage

The drainage from the pulp silo amounted to 405,000 gpd, or 163 gallons per ton of beets. Although this waste was of small quantity, only 3.6% of the volume of all factory wastes, it contributed a relatively large portion to the total BOD load.

The temperature of the waste averaged 27°C. The pH varied from 3.5 to 4.0, and the acidity as indicated by two determinations averaged 2,860 ppm as $CaCO_3$.

The BOD concentration varied from 6,590 to 11,400, and averaged 8,840 ppm. This amounts to 11.48 pounds per ton of beets, or approximately 27% of the total BOD loading discharged by the factory.

Suspended solids averaged 3,150 ppm, 97% of which were volatile. The volatile solids averaged 5,980 ppm. This waste was relatively high in nitrogenous material; it contained an average of 89 ppm organic nitrogen and 7.2 ppm ammonia nitrogen.

32. Steffens Waste

The average volume of the Steffens waste was 391,400 gpd. This amounted to 157 gallons per ton of beets, or 2,420 gallons per ton of 50% polarization molasses processed. This waste had a temperature of 80 to 85°C. The pH varied between 12.3 and 12.7, and the average phenolphthalein and total alkalinities were 5,590 and 8,210 ppm as $CaCO_3$, respectively.

The Steffens waste was one of the stronger wastes. The BOD varied between 9,300 and 12,200, and averaged 10,940 ppm. It amounted to 14.48 pounds per ton of beets, or 223 pounds per ton of 50% polarization molasses processed, and accounted for nearly one third of the total BOD load from the factory.

The average total solids content was 24,700 ppm, practically all of which were filtrable. Volatile solids averaged 10,950 ppm. This waste was very high in nitrogenous matter. The organic nitrogen content averaged over 800 ppm and the ammonia nitrogen [illegible] 6.5 ppm.

33. Filter Cake Waste

The average discharge of the filter cake waste was computed to be 325,000 gpd, or 135 gallons per ton of beets. The pH varied around 11.6, and the phenolphthalein and total alkalinities, as indicated by single determinations, were 3,300 and 59,400 mg/l(a), respectively. The BOD averaged 7,250 mg/l, varying from 6,280 to 8,100 mg/l. It amounted to 8.23 pounds of BOD per ton of beets, or 19.1% of the BOD loading from the factory.

The suspended and total volatile solids, as indicated by single determinations, were 145,000 and 17,200 mg/l, respectively. The average concentration for the organic nitrogen was 362 mg/l, and that for the ammonia nitrogen was 3.3 mg/l.

34. Combined Factory Waste

The average volume of the combined factory waste was 10,470,000 gpd, or 4,210 gallons per ton of beets processed. The temperature averaged 26°C.

(a) Since sampling in the laboratory was done volumetrically, and the filter cake waste had a specific gravity of 1.06±, analytical results for this waste are reported in milligrams per liter.

The effect of the filter cake and Steffens wastes was indicated by the high pH, which ranged between 10.4 and 11.2. Average phenolphthalein and total alkalinities were 274 and 2,388 ppm, respectively.

The BOD averaged 1,404 ppm, varying from 1,100 to 1,770 ppm. The total BOD load in the factory wastes was 49.7 pounds per ton of beets processed (6.7 pounds of which was unaccounted for in the summation of the loadings of the individual wastes). This amounted to a "Population Equivalent" of 298 people per ton of beets, and indicated that the BOD load in the wastes discharged from the factory was equivalent to normal domestic sewage from a city of 740,000 population.

The average suspended solids was 6,335 ppm, or 222 pounds per ton of beets, of which 31.8 pounds were volatile. The total volatile solids averaged 2,140 ppm, or 75.3 pounds per ton. The average organic and ammonia nitrogen concentrations were 69.7 and 2.9 ppm, respectively.

35. Summary

The average characteristics for the Steffens house beet factory wastes for a plant comparable to the Loveland Factory are shown in Table 2. The relative order of the strengths of these wastes according to their BOD was Steffens waste, pulp silo drainage, filter cake waste, diffusion battery waste, and flume water waste. The Steffens and filter cake wastes were very high in organic nitrogenous matter. All except the Steffens waste and pulp silo drainage were high in suspended solids. The pH of the Steffens and filter cake wastes was very high, while that for the pulp silo drainage shows a high acid intensity due to the active fermentation in the silo.

Of particular interest is Table 3 which shows the volumes of each waste in gallons and the BOD in pounds per ton of beets processed, also the per cent each waste contributes to the total flow and BOD loading. It is particularly significant to note that the Steffens and filter cake wastes, together with the pulp silo drainage, contributed nearly 80% of the total BOD load, but amounted to only 15.6% of the total flow. Exclusion of these wastes from the receiving waters would be equivalent to treatment providing 80% BOD reduction.

Table 4 gives solids expressed in pounds per ton of beets for each of these wastes. These data are significant if lagooning or clarification is considered. The filter cake waste contains 163 pounds, about one cubic foot, of suspended matter per ton of beets; and the flume water waste contained 90 pounds, or nearly 2/3 cubic foot, per ton. If these wastes are to be lagooned the silting problem must be considered.

TABLE 3 - AVERAGE VOLUMES AND BIOCHEMICAL OXYGEN DEMAND LOADINGS OF STEFFENS HOUSE BEET SUGAR WASTES - LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY, OCTOBER-NOVEMBER, 1949

WASTE	VOLUME		B.O.D.		POPULATION EQUIVALENT (a)
	Gal. per ton of beets	% of Total	Lb. per ton of beets	% of Total	persons per ton of beets per day
Flume Water	2620	58.4	4.90	11.4	29.4
Beet Washer (b)	500	11.1	0.94	2.2	5.6
Diffusion Battery	406	9.0	2.98	6.9	17.8
Steffens	157	3.5	14.48	33.7	86.7
Filter Cake	135	3.0	8.23	19.1	49.3
Pulp Silo Drainage	163	3.6	11.48	26.7	68.7
Ash Pit Drainage	510	11.4	-	0.0	-
Total	4491	100.0	43.01	100.0	257.5
Combined Factory	4210		49.72		298

(a) Based on 5-day, 20°C. B.O.D. of 0.167 lb./capita/day.

(b) Volume based on estimate for Windsor Factory data, B.O.D. assumed to be that of flume water waste.

TABLE 4 - AVERAGE TOTAL AND VOLATILE SOLIDS LOADINGS OF STEFFENS HOUSE BEET SUGAR FACTORY WASTES[a] - LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY, OCTOBER-NOVEMBER, 1949

WASTE	VOLUME gal/ton of beets	TOTAL SOLIDS Total lb/ton of beets	TOTAL SOLIDS Suspended lb/ton of beets	TOTAL SOLIDS Filtrable lb/ton of beets	VOLATILE SOLIDS Total lb/ton of beets	VOLATILE SOLIDS Suspended lb/ton of beets	VOLATILE SOLIDS Filtrable lb/ton of beets
Flume Water	2620	96.5	89.8	7.3	14.2	8.6	5.6
Diffusion Battery	406	6.1	3.5	2.6	3.9	2.7	1.2
Steffens House	157	32.4	0.1	32.6	14.3	0.1	14.7
Filter Cake	135	167.7	163.2	4.5	19.4	17.5	1.9
Pulp Silo Drainage	163	9.2	1.1	8.1	8.1	1.0	7.1
Total	3481	311.9	257.7	55.1	59.9	29.9	30.5
Combined Factory[b]	4210	284	222	62	75.3	31.8	43.5

(a) Weights are those computed using average data for volumes and solid determinations.

(b) Includes beet washer wastes and ash pit drainage, which are estimated to be 500 and 510 gallons per ton, respectively.

The total volatile suspended solids amounted to 31.8 pounds per ton. Although this value is high due to the inclusion of the volatile solids for the filter cake, data for which are obscured by the volatilization of carbon dioxide during the ignition of a waste containing calcium carbonate, it does indicate the presence of an appreciable amount of settleable or sludge producing organic material.

POSSIBLE REMEDIAL MEASURES

In considering the elimination, reduction or treatment of beet sugar factory waste, it appears desirable to compare the relative volumes and BOD loadings of the various wastes from several factories. Table 5 summarizes the data available.

The BOD load of the flume water waste from the Loveland Factory is high when compared to the other data. This may be due to the larger volume of water used or to the higher temperature of that water.

The beet washer and diffusion battery wastes have relatively low BOD loads; the principal difference being in the diffusion battery waste. This was probably due to the use of a continuous diffusion battery at this factory.

The BOD loading of the filter cake waste from the Loveland Factory is almost double that of filter cake waste from the Windsor Factory(7). This may have been due to the Steffens process used at the former, but not at the latter plant. Eldridge's data(5) are for settled filter cake waste and, therefore, are not comparable.

The pulp silo drainage from both the Loveland and Windsor factories has about the same BOD loading. Eldridge studied factories disposing of the pulp by pressing and drying and, thus, he gives no data on such waste.

The Steffens waste for this plant has a high BOD load when compared to that given by Eldridge.

TABLE 5 - COMPARISON OF THE VOLUME AND BIOCHEMICAL OXYGEN DEMAND OF COMPONENT WASTES FROM BEET SUGAR FACTORIES

	VOLUME Gallons per ton of beets			B.O.D. Lbs. per ton of beets		
WASTE	Loveland Factory	Windsor Factory	Eldridge's Data (a)	Loveland Factory	Windsor Factory	Eldridge's Data (a)
Flume Water	2620	1760	2200	4.90	2.85	3.70
Beet Washer	500	485		0.94	0.78	
Diffusion Battery	406 (b)	1420 (c)	660 (d)	2.98 (b)	5.54 (c)	6.77 (d)
Steffons	163 (e)	-	120	14.48 (e)	-	10.01
Filter Cake	135	46	75 (f)	8.23	4.28	0.70 (f)
Pulp Silo Drainage	157	270	-	11.48	12.37	-
Total	4491	3981	3055	43.01	25.82	21.18

(a) See reference (5), Bibliography.
(b) Continuous diffusion unit.
(c) Diffusion battery consisted of 14 cells, each with side dump gate at its bottom.
(d) Includes wastes from pulp presses as well as diffusion battery washings.
(e) Molasses worked was 6.26% on beets, 47.6% of which was shipped in from straight house factories.
(f) Effluent from settling lagoon.

Where a reduction in the pollution resulting from beet sugar wastes is desirable, consideration should be given to the reduction, or elimination, of certain component wastes. Although it is beyond the scope of this report to investigate the costs involved, it appears that at many plants the economics of such reduction or elimination of some of the waste may be more favorable than any presently known or indicated method of treatment. Possible methods, some of which are now in use at one or more plants, are discussed briefly below.

36. Flume Water and Beet Washer Wastes

Consideration should be given to the clarification and recirculation of flume water and beet washer wastes. Information was that recirculation of flume water has been practiced at the Eaton Factory of the Great Western Sugar Company. However, no data on this practice were available.

One Ohio factory (8), which reused these wastes, permitted an average of 250 gallons per ton of beets processed, or 6% to 8% of the total flume water waste, to overflow into the outfall sewer. In addition about 215 gallons of sludge for each ton of beets was withdrawn from the clarifier. The overflow was reported to have an average BOD of 1,320 ppm, and the sludge has been assumed to have at least equal strength. The overflow and sludge have a calculated BOD of 2.75 and 2.35 pounds per ton of beets, respectively. When compared to the data given in Table 5, it appears that the principal accomplishment was to concentrate the BOD load in rather small volumes, one of which was lagooned. The 6% to 8% overflow contained approximately 60% of the BOD loading found in flume water wastes at factories not using such recirculation. This indicates that the overflow, if any, as well as the sludge should be lagooned.

37. Diffusion Battery Waste

At most factories a substantial reduction in the BOD load of the diffusion battery waste may be made by replacing the older individual-cell type with a continuous type diffuser. At least such is indicated on comparing the BOD loading for this waste at the Loveland Factory with the data from the Windsor Factory and that given by Eldridge. A still greater reduction in this load could be obtained by eliminating the water-carriage system used for transporting the spent pulp. Such would appear particularly desirable wherever the pulp is to be pressed and dried (the installation of pulp presses and driers has already been authorized by the Great Western Sugar Company for the Loveland Factory).

In this case the only waste from this source would be from the pulp presses.

Throughout the 1949 campaign one Ohio factory (8) treated the diffusion battery and pulp press wastes and recycled them for process water and for washing the diffusion cells. An essential feature of this patented process is the addition of chlorine to control thermophilic bacteria. This process completely eliminated both the diffusion battery and pulp press wastes.

38. Pulp Silo Drainage

The installation of pulp presses and driers will completely eliminate pulp silo drainage. In some cases a very slight reduction in the B.O.D. load in this waste may be made by efficient screening of the diffusion battery waste to reduce the amount of liquor passing into the silo, also by a good underdrainage system to aid in removing the waste before extensive fermentation has increased its strength.

39. Filter Cake Waste

The filter cake waste is very strong, but small in volume. Complete retention in lagoons is indicated. Very limited data from the Windsor studies indicated 50% B.O.D. reduction may be obtained by passing it through a lagoon providing a very short detention period.

40. Steffens Waste

The eventual solution to the problem of the disposing of Steffens waste appears to be in its utilization as a source from which to recover sodium glutamate. It was reported that a process now under consideration for the Loveland Factory would completely eliminate this waste.

ACKNOWLEDGMENT

It is desired to express appreciation to Mr. A. A. Clark, Vice President and General Superintendent of the Great Western Sugar Company, whose interest resulted in this cooperative survey; to Mr. A. R. Nees, and other personnel of the Denver Office; and to Mr. F. A. Whiting, Manager; Mr. V. V. Hartman, Chief Chemist; and other personnel of the Loveland Factory for the cooperation and assistance extended during the conduct of this survey.

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APPENDIX A

Sampling data and Analytical Results

APPENDIX A. SAMPLING DATA AND ANALYTICAL RESULTS, LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY - OCTOBER-NOVEMBER, 1949

Sample	Date of Sampling 1949	Method of Collection and Compositing	Beets Processed Tons Per Day	Flow 24-Hr. Av. gpd	Temperature			pH	Total Alkalinity Ca CO$_3$ ppm	BOD 5-day 20° C ppm	Total Solids			Volatile Solids			Nitrogen	
					Min °C	Av °C	Max °C				Total ppm	Suspended ppm	Filtrable ppm	Total ppm	Suspended ppm	Filtrable ppm	NH$_3$ ppm	Organic ppm
Flume	Nov. 8	8-Hr. Com-	2586	Estimated	27	31	35	7.2	-	254	-	-	-	-	-	-	-	-
Water	Nov. 9	posite	2590	to Average	32	35	37	7.3	148	238	4650	4440	210	680	430	250	3.3	13.0
Waste-	Nov. 11	Consisting	2545	6,460,000	25	32	42	7.2	-	198	-	-	-	-	-	-	-	-
Up-		of 8 Equal		gpd.														
stream	Nov. 27	Portions	2576		30	33	38	8.1	-	262	-	-	-	-	-	-	3.0	18.4
from	Nov. 28	Collected	2551		30	35	39	7.5	142	236	3070	3140	0	480	310	170	-	-
Trash	Nov. 29		2568		26	29	33	8.0	-	237	5520	4760	760	790	440	350	-	-
Racks	Nov. 30	Hourly	2470		24	27	29	7.9	-	155	-	-	-	-	-	-	3.7	7.3
	Dec. 1		1834		22	28	35	8.0	-	201	-	-	-	-	-	-	-	-
	No. of Determinations		8			8		8	2	8	3	3	3	3	3	3	3	3
	Average		2465	6,460,000		31		7.7	145	223	4413	4113	333	650	393	257	3.3	12.9
	Maximum		2590			35	42	8.1		262								
	Minimum		1834		22	27		7.2		155								

APPENDIX A. SAMPLING DATA AND ANALYTICAL RESULTS, LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY - OCTOBER-NOVEMBER, 1949

Sample	Date of Sampling 1949	Method of Collection and Compositing	Beets Processed Tons Per Day	Flow 8-Hr. Av. gpd	Temperature Min °C	Temperature Av °C	Temperature Max °C	pH	Total Alkalinity Ca CO3 ppm	BOD 5-day 20°C ppm	Total Solids Total ppm	Total Solids Suspended ppm	Total Solids Filtrable ppm	Volatile Solids Total ppm	Volatile Solids Suspended ppm	Volatile Solids Filtrable ppm	Nitrogen NH3 ppm	Nitrogen Organic ppm
Diffu-	Oct. 17	8-Hr. Com-	2518	1,070,000	31	32	34	7.2	110	747	1750	1150	600	1360	1030	330	-	-
sion	Oct. 18	posite	2443	1,010,000	30	32	34	6.7	-	781	1850	1190	660	1200	870	330	-	-
Batt-	Oct. 19	Consisting	2483	940,000	28	29	30	7.0	130	1020	1930	930	1000	1120	780	340	-	-
ery	Oct. 20	of 8 Equal	2586	800,000	28	28	29	6.7	-	826	1860	830	1030	1240	680	560	-	-
Waste	Oct. 21	Portions	2451	870,000	27	28	29	6.5	-	941	1860	980	880	1190	790	400	-	-
A-Frame	Nov. 7	Collected	2549	920,000	27	29	30	6.9	99	1420	2000	1050	950	1230	770	460	-	-
Screen	Nov. 8	Hourly	2586	1,050,000	27	28	28	6.9	-	1320	-	-	-	-	-	-	5.0	30.5
Efflu-	Nov. 9		2590	1,090,000	27	28	28	6.9	100	899	1700	1210	490	1050	990	60	5.0	32.1
ent	Nov. 11		2545	820,000	26	28	31	7.2	-	1390	-	-	-	-	-	-	-	-
	Nov. 27		2576	1,150,000	24	26	28	6.9	-	501	1410	820	590	760	500	260	5.0	37.0
	Nov. 29		2568	1,220,000	23	24	24	6.9	115	533	-	-	-	-	-	-	-	-
	Dec. 1		1834	1,120,000	22	23	24	6.8	-	534	-	-	-	-	-	-	-	-
	No. of Determinations		12	12	12	12		12	15	12	8	8	8	8	8	8	3	3
	Average		2478	1,005,000		28		6.9	111	909	1795	1020	775	1143	801	342	5.0	33.2
	Maximum		2590	1,220,000		32	34	7.2	130	1420	2000	1210	1030	1360	1030	560		
	Minimum		1834	800,000	22	23		6.5	99	501	1410	820	490	760	500	60		

APPENDIX A . SAMPLING DATA AND ANALYTICAL RESULTS, LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY - OCTOBER-NOVEMBER, 1949

Sample	Date of Sampling 1949	Method of Collection and Compositing	Beets Processed Tons Per Day	Molasses[(a)] Worked Tons Per Day	Flow 24-Hr.Av. gpd	pH	Alk.as $CaCO_3$		BOD 5-day 20° C ppm	Total Solids			Volatile Solids			Nitrogen	
							Phth ppm	Total ppm		Total ppm	Suspended ppm	Filtrable ppm	Total ppm	Suspended ppm	Filtrable ppm	NH_3 ppm	Organic ppm
Steffens Waste	Oct. 17	8-Hour Composite Consisting of 8 Equal Portions Collected Hourly	2518	155.6	394,000	-	6770	10120	9800	22970	50	22920	8950	30	8920	-	-
	Oct. 18		2443	149.0	367,000	-	-	-	9900	24570	130	24440	10210	60	10150	-	-
	Oct. 19		2483	148.6	356,000	-	5320	7860	10200	27840	20	27820	15040	20	15020	-	-
	Oct. 20		2586	158.1	379,000	-	-	-	9300	22400	210	22190	9160	80	9080	-	-
	Oct. 21		2451	149.1	372,000	-	-	-	10400	27150	40	27110	13190	20	13170	-	-
	Nov. 7		2549	163.9	409,000	-	5240	7720	12000	23490	-	-	9960	-	-	-	-
	Nov. 8		2586	169.9	393,000	-	-	-	11700	-	-	-	-	-	-	-	-
	Nov. 9		2590	168.8	416,000	-	5600	7560	12200	-	-	-	-	-	-	2.3	863
	Nov. 11		2545	172.2	405,000	12.7	-	-	-	-	-	-	-	-	-	-	-
	Nov. 27		2576	171.8	400,000	12.6	-	-	11200	24550	-	-	10260	-	-	14.8	812
	Nov. 29		2568	172.6	414,000	12.6	5000	7800	11900	-	-	-	-	-	-	-	-
	Dec. 1		1834	150.2	371,000	12.4	-	-	10700	-	-	-	-	-	-	-	-
	No. of Determinations		12	12	12	4	5	5	12	7	5	5	7	5	5	2	2
	Average		2478	160.8	389,700	12.6	5586	8212	10940	24710	90	24896	10948	42	11268	8.5	838
	Maximum		2590	172.6	416,000	12.7	6770	10120	12200	27840	210	27820	13190	80	15020		
	Minimum		1834	148.6	356,000	12.4	5000	7560	9300	22400	20	22190	8950	20	8920		

(a) Adjusted to 50% polarization

APPENDIX A. SAMPLING DATA AND ANALYTICAL RESULTS, LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY - OCTOBER-NOVEMBER, 1949

Sample	Date of Sampling 1949	Method of Collection and Compositing	Beets Processed Tons Per Day	Flow 8-Hr. Av. gpd	Temperature			pH	Acidity As $CaCO_3$ ppm	BOD 5-day 20° C ppm	Total Solids			Volatile Solids			Nitrogen	
					Min °C	Av °C	Max °C				Total ppm	Suspended ppm	Filtrable ppm	Total ppm	Suspended ppm	Filtrable ppm	NH_3 ppm	Organic ppm
Pulp	Oct.17	8-Hr. Com-	2518	352,000	30	30	31	4.0	-	9000	6980	120	6860	6270	120	6150	-	-
Silo	Oct.18	posite	2443	394,000	31	31	31	3.9	-	7580	6490	300	6190	5760	150	5610	-	-
Drainage	Oct.19	Consisting	2483	313,000	27	28	29	3.9	-	9050	7400	280	7120	6710	210	6500	-	-
From	Oct.20	of 8 Equal	2586	371,000	24	27	29	3.9	-	9980	9940	690	9250	8960	650	8310	-	-
M.H.	Oct.21	Portions	2451	409,000	25	27	28	3.9	-	7880	6730	600	6130	5940	580	5360	-	-
North of Silo	Nov. 7	Collected Hourly	2549	406,000	27	28	29	3.9	-	7950	4940	250	4690	4090	230	3860	-	-
	Nov. 8		2586	475,000	27	28	28	3.9	-	8020	-	-	-	-	-	-	6.6	-
	Nov. 9		2590	550,000	27	27	27	3.9	-	9150	-	-	-	-	-	-	8.4	-
	Nov.11		2545	417,000	24	26	27	3.7	-	11400	-	-	-	-	-	-	-	-
	Nov.27		2576	377,000	27	27	27	3.9	-	6900	-	-	-	-	-	-	7.0	98.
	Nov.28		2551	388,000	26	26	27	3.6	-	8290	5420	1240	4180	4620	1140	3480	-	-
	Nov.29		2568	375,000	25	25	26	3.6	2720	8830	6330	3150	3180	5510	3060	2450	-	-
	Nov.30		2470	409,000	24	24	25	3.9	3000	7560	-	-	-	-	-	-	7.0	80.
	Dec. 1		1834	437,000	23	24	24	3.7	-	6590	-	-	-	-	-	-	-	-
	No. of Determinations		14	14		14		14	2	14	8	8	8	8	8	8	4	2
	Average		2482	405,200		27		3.8	2860	8841	6779	829	5950	5982	767	5215	7.2	89
	Maximum		2590	550,000		31	31	4.0		11400	9940	3150	9250	8960	3060	8310		
	Minimum		1834	313,000	23	24		3.6		6590	4940	120	3180	4090	120	2450		

APPENDIX A. SAMPLING DATA AND ANALYTICAL RESULTS, LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY - OCTOBER-NOVEMBER, 1949

Sample	Date of Sampling 1949	Method of Collection and Compositing	Beets Processed Tons Per Day	Flow 8-Hr. Av. gpd	Temperature			pH	Alk. as $CaCO_3$		BOD 5-Day 20°C ppm	Total Solids			Volatile Solids			Nitrogen	
					Min °C	Av. °C	Max °C		Phth ppm	Total ppm		Total ppm	Suspended ppm	Filtrable ppm	Total ppm	Suspended ppm	Filtrable ppm	NH_3 ppm	Organic ppm
Combined Factory Wastes	Oct.17	8-Hour Composite Consisting of 8 Equal Portions Collected Hourly	2518		22	28	32	-	710	2800	1100	6130	4640	1490	2220	790	1430	-	-
	Oct.18		2443		27	30	32	-	-	-	1500	9570	7030	2540	2300	1180	1120	-	-
	Oct.19		2483	10,400,000	24	26	29	-	200	2880	1140	7690	5720	1970	1890	910	980	-	-
	Oct.20		2586		24	25	28	-	-	-	1410	8550	6000	2550	2130	850	1280	-	-
	Oct.21		2451		22	25	28	-	-	-	1140	7680	5850	1830	1870	870	1000	-	-
	Nov. 7		2549		26	28	29	-	180	2300	1650	8800	7010	1790	2160	840	1320	-	-
	Nov. 8		2586		23	27	28	-	-	-	1460	-	-	-	-	-		2.7	74.4
	Nov. 9		2590		24	27	29	-	102	1680	1390	8100	6400	1700	2710	830	1880	2.8	70.7
	Nov. 11		2545		24	26	29	11.2	-	-	1770	-	-	-	-	-	-	-	-
	Nov. 27		2576	10,500,000	24	26	29	10.8	-	-	1350	8110	8030	80	1840	950	890	3.2	63.9
	Nov. 28		2551	10,100,000	25	26	28	10.4	180	1880	1470	-	-	-	-	-	-	-	-
	Nov. 29		2568	10,600,000	23	25	27	10.7	-	-	1630	-	-	-	-	-	-	-	-
	Nov. 30		2470	10,400,000	23	25	26	10.6	-	-	1230	-	-	-	-	-	-	-	-
	Dec. 1		1834	10,800,000	22	24	25	10.5	-	-	1410	-	-	-	-	-	-	-	-
	No. of Determinations		14	6		14		6	5	5	14	8	8	8	8	8	8	3	3
	Average		2482	10,470,000		26		10.7	274	2388	1404	8079	6335	1744	2140	902	1238	2.9	69.7
	Maximum		2590	10,800,000		30	32	11.2	710	2880	1770	9570	8030	2550	2710	1180	1880		
	Minimum		1834	10,100,000	22	24		10.4	102	1680	1100	6130	4640	80	1840	790	890		

APPENDIX A SAMPLING DATA AND ANALYTICAL RESULTS, LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY - OCTOBER-NOVEMBER, 1949

Sample	Date of Sampling 1949	Method of Collection and Compositing	Beets Processed Tons Per Day	Flow 24-Hr. Av. gpd	pH	Alk. as $CaCO_3$ Phth mg/1	Alk. as $CaCO_3$ Total mg/1	BOD 5-Day 20° C mg/1	Total Solids Total mg/1	Total Solids Suspended mg/1	Total Solids Filtrable mg/1	Volatile Solids Total mg/1	Volatile Solids Suspended mg/1	Volatile Solids Filtrable mg/1	Nitrogen NH_3 mg/1	Nitrogen Organic mg/1
Filter Cake Wastes	Nov. 27	8-Hour Composite Consisting of 8 Equal Portions Collected Hourly	2576	294,000	11.6	-	-	7700	-	-	-	-	-	-	3.5	408
	Nov. 28		2551	318,000	11.5	3300	59400	7790	-	-	-	-	-	-	-	-
	Nov. 29		2568	338,000	11.6	-	-	8100	149000	145,000	4000	17200	15,500	1,700	-	-
	Nov. 30		2470	361,000	11.6	-	-	6280	-	-	-	-	-	-	3.0	317
	Dec. 1		1834	314,000	11.5	-	-	6420	-	-	-	-	-	-	-	-
	No. of Determinations		5	5	5	1	1	5	1	1	1	1	1	1	2	2
	Average		2400	325,000	11.6	3300	59400	7258	149000	145,000	4000	17200	15,500	1700	3.3	362
	Maximum		2576	361,000	11.6			8100								
	Minimum		1834	294,000	11.5			6280								

APPENDIX B

B.O.D. Data, Including Population Equivalent, for Steffens House Beet Sugar Factory Wastes

APPENDIX B - B.O.D. DATA, INCLUDING POPULATION EQUIVALENT FOR STEFFENS HOUSE BEET SUGAR FACTORY WASTES - LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY

Sample	Date 1949	Beets Processed tons/day	Flow 8-hr. Av. gpd	BIOCHEMICAL OXYGEN DEMAND ppm	lb/day	lb/ton	Population Equivalent persons/ton/day
Flume Water Waste	Nov. 8	2586	Estimated at 6,460,000	254	13700	5.30	31.8
	Nov. 9	2590		239	12900	4.98	29.8
	Nov.11	2545		198	10700	4.20	25.1
	Nov.27	2576		262	14100	5.47	32.9
	Nov.28	2551		236	12700	4.98	29.8
	Nov.29	2568		237	12800	4.98	29.8
	Nov.30	2470		155	8400	3.40	20.4
	Dec. 1	1834		201	10800	5.88	35.3

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	Average	2465	6,460,000	223	12010	4.90	29.4
	Maximum	2590		262	14100	5.88	35.3
	Minimum	1834		155	8400	3.40	20.4

APPENDIX B - B.O.D. DATA, INCLUDING POPULATION EQUIVALENT FOR STEFFENS HOUSE BEET SUGAR FACTORY WASTES - LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY

Sample	Date 1949	Beets Processed tons/day	Flow 8-hr. Av. gpd	BIOCHEMICAL OXYGEN DEMAND ppm	lb/day	lb/ton	Population Equivalent persons/ton/day
Diffusion Battery Waste	Oct. 17	2518	1,070,000	747	5660	2.25	13.5
	Oct. 18	2443	1,010,000	781	6570	2.69	16.1
	Oct. 19	2483	940,000	1020	7630	3.07	18.4
	Oct. 20	2586	800,000	826	5510	2.13	12.7
	Oct. 21	2451	870,000	941	6830	2.79	16.7
	Nov. 7	2549	920,000	1420	10890	4.27	25.6
	Nov. 8	2586	1,050,000	1320	11560	4.47	26.7
	Nov. 9	2590	1,090,000	899	8170	3.65	21.8
	Nov. 11	2545	820,000	1390	9500	3.74	22.3
	Nov. 27	2576	1,150,000	501	4910	1.91	11.4
	Nov. 29	2568	1,220,000	533	5430	2.11	12.6
	Dec. 1	1834	1,120,000	534	4990	2.72	16.3

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Average	2478	1,005,000	909	7304	2.98	17.8
Maximum	2590	1,220,000	1420	11560	4.47	26.7
Minimum	1834	800,000	501	4910	1.91	11.4

APPENDIX B - B.O.D. DATA, INCLUDING POPULATION EQUIVALENT FOR STEFFENS HOUSE BEET SUGAR FACTORY WASTES - LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY

Sample	Date 1949	Beets Processed tons/day	Molasses (50% polarization) Worked tons/day	Flow 24-hr. Av. gpd	BIOCHEMICAL OXYGEN DEMAND					
					ppm	lb/day	lb/ton		Population Equivalent persons/ton/day	
							Beets	Molasses	Beets	Molasses
Steffens Waste	Oct. 17	2518	155.6	394,000	9800	32200	12.8	207	76.6	1240
	Oct. 18	2443	149.0	367,000	9900	30300	12.4	204	74.3	1220
	Oct. 19	2483	148.6	356,000	10200	30300	12.2	204	73.0	1220
	Oct. 20	2586	158.1	379,000	9300	29400	11.4	185	68.2	1110
	Oct. 21	2451	149.1	372,000	10400	32200	13.1	216	78.4	1280
	Nov. 7	2549	163.9	409,000	12000	41000	16.1	250	96.4	1500
	Nov. 8	2586	169.9	393,000	11700	38400	15.0	226	89.8	1350
	Nov. 9	2590	168.8	416,000	12200	42400	16.4	252	98.1	1510
	Nov. 11	2545	172.2	405,000	12000	40600	15.9	235	95.2	1410
	Nov. 27	2576	171.8	400,000	11200	37300	14.5	217	86.8	1300
	Nov. 29	2568	172.6	414,000	11900	41200	16.0	238	95.8	1420
	Dec. 1	1834	150.2	371,000	10700	33100	18.0	220	107.8	1320
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	Average	2478	160.8	389,700	10940	35700	14.48	221.2	86.8	1322
	Maximum	2590	172.6	416,000	12200	42400	18.0	252	107.8	1510
	Minimum	1834	148.6	356,000	9300	29400	11.4	185	68.2	1110

APPENDIX B - B.O.D. DATA, INCLUDING POPULATION EQUIVALENT FOR STEFFENS HOUSE BEET SUGAR FACTORY WASTES - LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY

Sample	Date 1949	Beets Processed tons/day	Flow 24-hr. Av. gpd	BIOCHEMICAL OXYGEN DEMAND ppm	lb/day	lb/ton	Population Equivalent persons/ton/day
Filter Cake Waste	Nov. 27	2576	294,000	7700	18900	7.34	43.9
	Nov. 28	2551	318,000	7780	20700	8.12	48.7
	Nov. 29	2568	338,000	8100	22800	8.87	53.2
	Nov. 30	2470	361,000	6280	18900	7.65	45.8
	Dec. 1	1834	315,000	6410	16800	9.16	54.9

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		Beets Processed tons/day	Flow 24-hr. Av. gpd	ppm	lb/day	lb/ton	Population Equivalent persons/ton/day
	Average	2400	325,200	7254	19620	8.23	49.3
	Maximum	2576	361,000	8100	22800	9.16	54.9
	Minimum	1834	294,000	6280	16800	7.34	43.9

APPENDIX B – B.O.D. DATA, INCLUDING POPULATION EQUIVALENT FOR STEFFENS HOUSE BEET SUGAR FACTORY WASTES – LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY

Sample	Date 1949	Beets Processed tons/day	Flow 8-hr. Av. gpd	BIOCHEMICAL OXYGEN DEMAND ppm	lb/day	lb/ton	Population Equivalent persons/ton/day
Pulp Silo Drainage	Oct. 17	2518	352,000	9000	26400	10.5	62.9
	Oct. 18	2443	394,000	7580	24800	10.0	59.9
	Oct. 19	2483	313,000	9050	23600	9.5	58.8
	Oct. 20	2586	371,000	9980	30900	11.9	71.2
	Oct. 21	2451	409,000	7880	26900	11.0	65.9
	Nov. 7	2549	406,000	7950	26900	10.5	62.9
	Nov. 8	2586	475,000	8020	31800	12.3	73.7
	Nov. 9	2590	550,000	9150	41900	16.2	97.0
	Nov. 11	2545	417,000	11400	39700	15.6	93.4
	Nov. 27	2576	377,000	6900	21700	8.5	51.9
	Nov. 28	2551	388,000	8290	26800	10.5	62.9
	Nov. 29	2568	375,000	8830	27600	10.7	64.0
	Nov. 30	2470	409,000	7560	25800	10.4	62.3
	Dec. 1	1834	437,000	6590	24100	13.1	78.5
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	Average	2482	405,200	8441	28490	11.48	68.7
	Maximum	2590	550,000	11400	41900	16.2	97.0
	Minimum	1834	313,000	6590	21700	8.5	51.9

APPENDIX B - B.O.D. DATA, INCLUDING POPULATION EQUIVALENT FOR STEFFENS HOUSE BEET SUGAR FACTORY WASTES - LOVELAND FACTORY, GREAT WESTERN SUGAR COMPANY

Sample	Date 1949	Beets Processed tons/day	Flow 8-hr. Av. gpd	BIOCHEMICAL OXYGEN DEMAND ppm	lb/day^(a)	lb/ton^(a)	Population Equivalent persons/ton/day
Combined Factory Waste	Oct. 17	2518	10,400,000	1100	96000	38.1	238
	Oct. 18	2443		1500	131000	53.6	321
	Oct. 19	2483		1140	99000	39.8	238
	Oct. 20	2586		1410	123000	47.6	285
	Oct. 21	2451		1140	99000	40.4	242
	Nov. 7	2549		1650	144000	56.5	338
	Nov. 8	2586		1460	127000	49.1	294
	Nov. 9	2590		1390	121000	46.7	280
	Nov. 11	2545		1770	154000	60.5	362
	Nov. 27	2576	10,500,000	1350	118000	45.8	274
	Nov. 28	2551	10,100,000	1470	124000	48.6	291
	Nov. 29	2568	10,600,000	1630	144000	56.1	336
	Nov. 30	2470	10,400,000	1230	107000	43.3	260
	Dec. 1	1834	10,800,000	1410	127000	69.2	414
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	Average	2482	10,460,000	1404	122400	49.7	298
	Maximum	2590	10,800,000	1770	154000	69.2	414
	Minimum	1834	10,100,000	1100	96000	38.1	238

(a) Average flow has been used to compute data for days for which flow is not recorded.